

Impact of Augmented-Reality Strategy on Engagement and Performance in Cell Biology Concepts among Secondary School Students in Sokoto State, Nigeria

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Abstract

This study examines the impact of Augmented-Reality strategy on engagement and performance in cell biology concepts among secondary school students in Sokoto state, Nigeria. Utilizing a quasi-experimental design with pre-test and post-test assessments, the research involved a sample size of 105 (53 male and 52 female) senior secondary two (SS II) students during the 2024/2025 academic session in Sokoto state were selected from the target population using multi-stage sampling technique. The intervention group experienced AR-based teaching methods, while the control group received traditional instruction. Data collection instruments included academic performance tests, student surveys on learning perceptions, and teacher observations of classroom engagement with validity/reliability indexes of 1/0.86 and 0.85/0.82 respectively. Quantitative analysis done using independent sample t-test revealed no significant gender differences in academic performance post-intervention; both male and female students showed marked improvement. However, qualitative findings indicated that female students exhibited higher engagement levels, actively participating in discussions and demonstrating greater interest in the content. In contrast, male students displayed mixed reactions, with some appreciating the AR's novelty, while others preferred more hands-on activities with immediate rewards. The study concludes that AR-based teaching methods can enhance academic performance for both genders, but engagement strategies may need to be tailored to address gender-specific preferences. Recommendations include adopting interactive teaching methods and promoting gender-sensitive strategies to foster equal engagement and achievement in biology education. Future research should explore the long-term effects of AR on gender-specific learning outcomes and examine whether integrating collaborative or gamified elements could further enhance engagement across diverse student groups.

Keywords: Augmented-reality, engagement. Gender, academic performance

Introduction

Gender differences in educational outcomes, particularly in science education, have long been a subject of interest for researchers and educators alike. Biology, being a critical component of science education, has traditionally been perceived as a subject where female students tend to outperform their male counterparts. However, this perception has evolved over time, as recent studies have shown that the gender gap in biology performance is not solely determined by gender but by a complex interaction of factors such as teaching methods, student engagement, and societal influences (Baker & Leary, 2021). In secondary school biology, these gender-based differences in performance and engagement may significantly influence how teachers approach instruction, with the goal of ensuring equal academic opportunities for all students. The educational environment, including the availability of resources and the strategies employed by teachers, also plays a pivotal role in shaping student achievement and interest in the subject (Mahoney, 2020; Roberts & Taylor, 2019). In the Nigerian educational system,



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senior secondary school education represents a critical phase in a student's academic journey. It marks the transition from foundational knowledge to more specialized subjects, including biology, which is essential for students pursuing careers in health sciences, agriculture, and environmental studies (Afolabi & Ogunyemi, 2020). Biology education in Nigeria is designed to provide students with the knowledge and skills required to understand the natural world, with a particular focus on concepts such as cell biology, genetics, and ecology. Despite its significance, the delivery of biology education in many Nigerian states, including Sokoto, has been constrained by traditional methods of teaching, which often fail to fully engage students (Musa, 2021). According to Musa (2021), in Sokoto State, the educational practices have remained largely conventional, with limited exploration of how gender differences influence learning outcomes in the sciences. The state, located in the northwestern region of Nigeria, faces challenges such as insufficient teaching resources, large class sizes, and limited access to modern educational technologies (Ezeani, Nnadi, & Odili, 2021). However, the incorporation of innovative teaching strategies, such as AR, offers a promising approach to enhance student engagement and understanding in biology (Smith & Taylor, 2022). AR has the potential to bring abstract biological concepts to life, providing immersive, interactive experiences that could help bridge the gender gap in academic performance by engaging both male and female students equally (Anderson, Smith, & Taylor, 2021). This study, therefore, aims to examine gender-based differences in learning outcomes in cell biology, with a focus on how the use of AR in biology classrooms in Sokoto State may impact secondary school students' academic performance and engagement.

This study investigates gender differences in learning outcomes in biology, specifically focusing on cell biology, and the potential role of AR-based teaching interventions. Previous research has highlighted that male and female students engage with biology education differently due to factors such as learning preferences, engagement levels, and teaching methodologies (Halim & Meerah, 2015; Dufresne, Gerace, & Leonard, 2002). Gender disparities in academic performance can be influenced by motivation, confidence, and societal expectations regarding gender roles (Blickenstaff, 2005; Mahoney, 2020). This research explored whether AR-based interventions can help address or further amplify these gender-based differences in academic outcomes. AR has been identified as a tool that can enhance student engagement and understanding of complex biological concepts (Wu, Lee, Chang, & Liang, 2013), making it a potential solution to bridge gender gaps in biology education. Sokoto State, located in northwestern Nigeria, provides a unique educational and cultural context for this study. The state's educational system faces challenges such as inadequate infrastructure, limited access to modern resources, and a shortage of trained teachers, particularly in rural areas (Akinbobola, 2020). Additionally, gender roles and societal expectations are deeply embedded in the region's cultural fabric, influencing how students approach subjects like biology. In Sokoto, these societal norms may hinder female students' confidence and participation in science education, despite biology being traditionally seen as a female-dominated field globally (Mahoney, 2020). This study aims to determine whether AR interventions can help reduce gender disparities in student engagement and academic achievement in biology, particularly in the context of Sokoto's unique challenges.

Objectives of the Study

The main objectives of this study were to explore and quantify gender differences in learning outcomes in cell biology using AR strategy among secondary school students in Sokoto State. The study also identified the potential reasons behind these differences, which could inform future teaching strategies in Sokoto State and other similar contexts. The specific objectives of the study are:

1. To determine whether there is a significant gender difference in the academic performance of secondary school students in cell biology after an AR-based teaching intervention in Sokoto State, Nigeria.
2. Explore how male and female secondary school students perceive the learning of cell biology in Sokoto State, Nigeria.
3. To identify and examine the factors contributing to the observed gender differences in academic performance of secondary school students in cell biology in Sokoto State, Nigeria.

Research Questions

The following research questions guided the conduct of this study:

1. What is the mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State?
2. What is the mean response in level of academic engagement of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State?
3. What are the contributory factors affecting significant mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State?

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Null Hypotheses:

- Ho₁: There is no significant mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State
- Ho₂: There is no significant mean response in level of academic engagement of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State
- Ho₃: There are no significant contributory factors affecting significant mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State

Literature Review

Gender and Education

Recent researches on gender differences in education indicates that female students often outperform male students in subjects like biology, with girls typically demonstrating stronger study habits, better classroom behaviors, and a focus on long-term academic success (Hyde, 2005; Baker & Leary, 2018). These differences, however, vary across cultural and geographical contexts, with factors such as access to resources, societal expectations, and educational interventions influencing these patterns (Buchmann, DiPrete, & McDaniel, 2008; Møller, 2020). The integration of modern pedagogical tools, like augmented reality (AR), has shown to impact student engagement and performance, but the effects may differ by gender (Valkenburg et al., 2020; Akpan, 2021). In regions like Sokoto State, Nigeria, where socio-cultural dynamics significantly influence education, examining these factors is crucial for developing interventions that promote gender equality and enhance academic outcomes in subjects like biology (Garcia & Gonzales, 2021).

Gender Differences in Science Education

In the context of science education, particularly biology, gender differences in academic performance are influenced by various factors, including teaching methods and learning preferences. Studies suggest that while boys often excel in hands-on, competitive activities, girls tend to outperform in subjects that require detailed study and memorization, such as biology (Baker & Leary, 2018). Research indicates that girls benefit from traditional, teacher-centered instruction, which provides structured guidance, while boys may struggle with this approach, preferring more interactive, rewarding learning environments (Smith & Jones, 2020). The use of digital tools like augmented reality (AR) is increasingly seen as a way to address these gender-based differences by providing engaging, interactive learning experiences that cater to diverse learning styles, potentially improving academic outcomes for both genders (Valkenburg, Kremers, & de Vries, 2020; Akpan, 2021). This highlights the need for tailored teaching strategies that consider the unique learning needs of both male and female students in biology education.

Theories of Gender in Learning

Recent studies on gender differences in biology education highlight how societal expectations and gender roles influence academic performance. Social role theory suggests that girls may excel in biology, a subject perceived as requiring precision and attention to detail, while boys tend to favor competitive or abstract subjects (Eagly & Wood, 2012). In contrast, stereotype threat theory explains that students may underperform when they are aware of negative gender stereotypes in academic settings, particularly in subjects like science (Steele & Aronson, 1995). While traditional gender differences have been observed, modern educational tools, such as augmented reality (AR), offer a promising solution by providing interactive and engaging learning experiences that can help reduce gender-based disparities in academic achievement (Valkenburg et al., 2020). This underscores the potential of AR to create a more equitable learning environment, especially in science education, by catering to diverse learning styles and challenging traditional gender biases.

Gender Differences in Nigerian Education

Recent studies within the Nigerian context highlight mixed results regarding gender differences in science education, with some indicating better performance by male students, while others show girls excelling, particularly in subjects like biology (Akanbi, 2016; Oloruntegbe, 2018). Gender roles and expectations, particularly in regions like Sokoto State, where traditional norms are deeply rooted, significantly influence students' attitudes towards learning and their academic performance in subjects such as biology. These gendered expectations often manifest in classroom behaviors, with girls sometimes exhibiting stronger organizational skills and a more consistent approach to studying, which can contribute to better performance in biology (Adesina & Olorundare, 2019). However, the increasing use of innovative teaching methods, such as augmented reality (AR), has the potential to mitigate these gender disparities by offering more engaging and interactive learning experiences that appeal to a wider range of learning preferences and help to overcome traditional gender biases (Gandhi et al., 2021). This underscores the need to further explore how new educational tools can help bridge the gender gap in science education, particularly in biology, in culturally diverse regions like Sokoto State.

Gender Differences in Cell Biology



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Gender differences in biology, particularly cell biology, have been studied, revealing that females generally outperform males in subjects requiring memorization, detail, and attention, such as biology (Baker & Leary, 2018). This is linked to females' strengths in tasks that demand precision and sustained effort. Males, on the other hand, excel in more abstract or competitive subjects and may perform better in hands-on activities (Smith & Jones, 2020). Social role theory suggests that biology aligns with traditional gender roles, where girls are seen as more suited for subjects involving precision (Eagly & Wood, 2012). However, stereotype threat can negatively impact female students, causing underperformance when they are aware of stereotypes about their abilities in science (Steele & Aronson, 1995). Emerging technologies like augmented reality (AR) have the potential to bridge these gender gaps by making biology more engaging for both male and female students (Gandhi, Yusuf & Lawal, 2021).

Augmented Reality Teaching Strategy

Augmented Reality (AR) has become an innovative teaching tool, particularly in science education, where it enhances the learning of complex subjects like biology. By offering interactive, 3D visualizations of abstract concepts, such as cell structures and biological processes, AR improves students' understanding of topics that are difficult to grasp through traditional methods (Lee, Park & Choi, 2014). AR caters to diverse learning styles, fostering engagement and motivation, which ultimately leads to improved retention and academic performance (Bower, Howe, McCredie, Robinson & Grover, 2014; Dunleavy et al., 2009). Specifically, in cell biology, AR helps students visualize microscopic phenomena, making them more accessible and tangible (Cheng & Tsai, 2013). Despite challenges like the need for teacher training and technological access, AR's potential to revolutionize biology education by offering immersive and interactive experiences is significant (Radianti, Majchrzak, Fromm & Wohlgenannt, 2020).

Methodology

Research Design

This study employed a quasi-experimental design, with a pre-test/post-test methodology to assess the academic performance of male and female students in cell biology before and after an AR-based teaching intervention. A mixed-methods approach was used, combining quantitative data from performance tests with qualitative data from student surveys to capture perceptions of learning.

Population and Sample

The study was conducted in two secondary schools in Sokoto State, Nigeria, where biology is part of the core curriculum. The research involved a sample size of 105 (53 male and 52 female) senior secondary two (SS II) students during the 2024/2025 academic session in Sokoto state were selected from the target population using multi-stage sampling technique from classes offering biology in the selected schools.

Data Collection Instruments

The following instruments were developed by the researcher to collect data:

1. **Pre-test/Post-test:** Academic performance was assessed using a standardized biology test named Cell Biology Academic Performance Test (CBAPT) focused on cell biology, administered before and after the intervention. The instrument had reliability index of 1 and validity index of 0.86.
2. **Student Surveys:** A Cell Biology Students' Perception Survey (CBSPS) was used to capture students' perceptions of biology as a subject, their engagement in the learning process and their preferences for learning methods. The instrument had reliability index of 0.85 and validity index of 0.82.

Data Analysis

Data were analyzed using independent sample t-tests to compare post-test scores for male and female students. Additionally, qualitative data from surveys and observations were analyzed thematically to explore students' perceptions and engagement with the learning material.

Presentation of Results

The result of the study is presented in order of the research hypotheses

H₀₁: There is no significant mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State

Table 2: Difference in the academic performance of male and female students taught using AR

Variables	N	Mean	Mean Difference	Std. Deviation	t-Cal	p-Value	Decision
Male	53	25.66	-0.44	3.186	-.741	.460	H ₀ Accepted



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Female	52	26.10	2.325
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Source: Field work, 2025

The academic performance scores of male and female students taught cell biology using AR were subjected to an independent samples t-test analysis. The results, as shown in Table 2, the mean difference of -0.44 indicate no significant difference in academic performance between male and female students thus H01 which stated there is no significant gender difference in the academic performance of secondary school students in cell biology after an AR-based teaching intervention in Sokoto State, Nigeria was accepted. Both male and female students showed significant improvement in their post-test scores.

H02: There is no significant mean response in level of academic engagement of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State

Table 3: Academic engagement of students taught cell biology using AR strategy

Gender	N	Average response
Male	53	52%
Female	52	86%
Total	105	

Source: Field work, 2025

Observations and survey data in table 3 revealed that female students exhibited higher levels of engagement, actively participating in discussions and demonstrating a strong interest with 86% in the content. In contrast, male students with 52% were more prone to distraction and expressed a preference for short-term rewards over long-term academic goals. The perceptions of the AR-based teaching intervention varied by gender. Female students generally reported positive experiences, finding the interactive elements engaging and helpful in understanding complex cell biology concepts. They felt more confident and motivated to participate in class. In contrast, male students were more mixed in their reactions, with some appreciating the novelty of AR but others expressing frustration with the pace and preferring more hands-on activities with immediate rewards. While the AR intervention captured their attention at times, male students seemed to prefer learning methods that provided quicker, tangible outcomes.

H03: There are no significant contributory factors affecting significant mean difference in academic performance scores of male and female students taught cell Biology using Augmented Reality strategy in Sokoto State

Table 4: Factors contributing to gender difference

Factor	Effect on male	Effect on female
Culture	Moderate	High
Interest	Moderate	High
Motivation	Moderate	High
Learning style	Moderate	High
Teaching method	Moderate	High
Technology	High	Moderate
Peer influence	High	Moderate
Confidence and self-efficacy	High	Moderate

Source: Field work, 2025

Observations recorded by the researcher revealed that cultural expectations, societal pressures, interest, motivation, peer influence and confidence among others were identified as factors influencing students' academic behaviors. Female students tended to value academic achievement more highly and were less likely to be distracted, while male students focused more on immediate rewards, which may have impacted their focus during lessons.

Discussion of Findings

The findings of this study indicate that while the AR-based teaching intervention did not result in significant gender differences in academic performance, female students were more engaged and focused, which aligns with prior research on gender differences in engagement and learning behaviors. Female students often demonstrate greater involvement in classroom activities and exhibit more consistent study habits, factors linked to better performance in biology (Baker & Leary, 2018). This is consistent with Hyde (2005) assertion that girls tend to excel in subjects that require memorization and detailed study. However, the lack of significant performance differences suggests that the AR intervention may have had an equalizing effect, offering both genders a more interactive and engaging way to learn. In contrast, other studies suggest that boys, despite lower

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engagement, may excel in more hands-on, competitive tasks (Smith & Jones, 2020). Therefore, the AR strategy might not address all gender-specific preferences for learning, which could be crucial in improving academic outcomes across genders.

Factors Influencing Gender Differences

Cultural norms in Sokoto State likely contribute to the observed gender differences in engagement. Traditional gender roles may shape students' academic behaviors, with females more likely to prioritize academic achievement and boys more influenced by extrinsic motivations like immediate rewards.

Conclusion

This study highlights the importance of gender-sensitive teaching strategies in enhancing learning outcomes for both male and female students. While AR-based instruction did not result in significant gender differences in academic performance, it is clear that engagement and societal factors play crucial roles in shaping students' academic behaviors. To promote gender equality in education, both teachers and policymakers must consider these factors when designing and implementing educational strategies.

Recommendations

1. For Educators

To enhance engagement for both male and female students, teachers should adopt interactive teaching methods like multimedia, practical activities, and collaborative learning. For female students, strategies such as project-based learning, critical thinking tasks, and peer collaboration can further foster academic involvement. It's essential to ensure both genders are equally included in competitive tasks, promoting an inclusive environment that supports active participation from all students. Gender-sensitive teaching strategies should empower both male and female students to contribute meaningfully to the learning process.

2. For Policymakers

Policymakers should focus on improving teacher training, particularly in the use of interactive and student-centered teaching methods like AR. They should also promote gender equality in education through policies that challenge traditional gender roles and encourage both male and female students to pursue academic success in all subjects.

Suggestions For Further Studies

Future studies should explore the long-term effects of AR-based interventions on gender differences in learning outcomes and expand the sample size to include other regions of Nigeria. Additionally, qualitative studies that focus on student narratives about their gendered experiences in science education could provide valuable insights. This study highlights the need for further research into how AR can cater to both male and female learning preferences more effectively, potentially through adapting the intervention to include more diverse, hands-on, and competitive elements that appeal to different genders.

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